A Mobile Application for Psychological Assessment

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Abstract

The appearance of a twenty-four hours, seven days a week society in developed countries, lead to an increase in sleep debt among the population. This impairment provokes several physiological and cognitive diseases, such as, obesity, diabetes, cardiovascular and gastrointestinal diseases and other problems associated with cognitive functions, like short-term memory and attention deficits. Thus, early and accurate diagnosis is crucial for the accomplish of suitable treatment.The current tools for psychological assessment need a wide range equipment. From devices for performance tasks to sleep diaries and sleep scales data collection.

In the last few years several innovations in the mobile technologies field lead to an unprecedented evolution in smartphones. The presented work in this paper purposes an Electronic Psychological Profiler (ePP), an Android application that takes advantage of smartphones capabilities to create an embedded system, easy to use, and available for the general population.

All the information regarding how the application works, along with visual examples for better understanding, are provided. The final result was highly satisfactory, comprising a sleep diary, PVT and n-back tasks, a Karolinska Sleepiness Scale (KSS) and a Samn-Perelli Fatigue Checklist (SFC), along with a new approach for vigilance measurement during a long and continuous period of time. The collected data can easily be accessed and analyzed by physicians, hence, the ePP provides a quicker and friendly interface for psychological assessment.

Keywords: Sleep, Memory, Attention, Application, Android, Psychological

1 Introduction

The appearance of a twenty-four hours, seven days a week society in developed countries, lead to an increase in sleep debt among people.[3] Sleep disorders besides causing impairments to the day-to-day routines of people, also contribute to several other diseases, such as, obesity, cardiovascular and gastrointestinal problems and brain neurodegenerative diseases, like Alzheimer. Hence, early and accurate diagnosis is crucial for the accomplish of suitable treatment.[3],[26].

Current methods for diagnosis of sleep problems comprise polysomnography (PSG), actigraphy, oximetry, sleep diaries and performance tasks. PSG is the standard tool for this assessment as it allows a complete analysis of the sleep cycle regarding brain activity during sleep. It is a very powerful resource but with downside of being a costly exam and because of its complexion, must be supervised by a technician, thus being made in laboratory or clinical environments.[22],[9]

Sleep diaries are assessment used to perceive the individual sleep routines. These questionnaires are often made by hand, with the need for large volumes of paper to account for long periods of analysis.

Other useful tools are frequently applied, such as performance tasks, like Psychomotor Vigilance Task (PVT) and n-back tasks. Normally, these procedures need specific devices for each one of them, hence, totalizing a large number of equipments that a patient must carry on with.

With the technological revolution in mobile phones, a new concept may be in the horizon. Nowadays, smartphones are small computers with powerful computational capabilities, thus, being the perfect means to apply all the aforementioned systems.

2 Background

2.1 Sleep

Throughout history, several attempts to define sleep were made. It is known that all animals evolved a devision of behavioral states: activity, or adaptive behavior, and rest, or behavioral quiescence. For mammals, specifically, these states are known as wake and sleep. In ancient Greece, Hippocrates defined sleep as the cooling of blood, thus causing a shut down of the body. In turn, Aristotle, described sleep and wakefulness as opposites but necessary processes, controlled by a central organ responsible for sense perception.

In the beginning of the 20th century the first scientific explanations for sleep mechanisms arose, nevertheless, only in the 50's, with the evolution of Electroencephalography (EEG) and new anatomical, histochemical and biomolecular methods, was possible to study neuronal networks and brain activity, and start to understand the mechanisms underlying sleep and wakefulness. With EEG was possible to divide sleep in two different stages, Rapid Eye Movement (REM) sleep and Non-rapid Eye Movement (NREM) sleep.[15][8][16]

2.1.1 Sleep Disorders

Sleep disorders are conditions which can result from various problems associated with circadian rhythm dysfunctions, inability to initiate and maintain sleep or medical conditions. The American Academy of Sleep Medicine classifies sleep disorders in three major groups. Dyssomnias, characterized by excessive sleepiness or difficulty in initiating and maintain sleep. These are the primary disorders associated with disturbed sleep or impaired wakefulness, they are divided in intrinsic, extrinsic and circadian rhythm disorders. The second category, Parasomnias, are related to arousal disorders and sleep stage disorders, thus being divided in these two groups and REM associated disorders. These conditions do not cause primary complaints of insomnia or excessive sleepiness. The third category comprises the sleep disorders associated with mental, neurological or other medical conditions. [1] Such disorders can be: 1. Narcolepsy 2. Obstructive Sleep Apnoea Syndrome (OSAS) 3. Periodic Limb Movement Disorder (PLMD) 4. Restless Legs Syndrom (RLS) 5. Shift Work Sleep Disorder (SWSD) 6. Delayed Sleep Phase Syndrome (DSPS) 7. Short-Term Memory (STM)

3 Short-Term Memory (STM)

STM is an important cognitive function necessary for the execution of tasks that require holding and manipulating information for short periods of time. Baddeley, in 1986 defined STM as ”the temporary storage of information that is being processed in any of a range of cognitive tasks" Contrary to long-term memory there are no structural changes involved[1], hence, being a transient phenomenon.[17][21] We are not conscious aware of every accessible information stored in our STM.[5]

This cognitive process is very important in maintaining the ability to perform day-to-day tasks. When referring to the STM used to plan and carry out behavior its common to use the term working memory, e.g., remembering partial results when doing arithmetic calculations without paper.[6]

There are different types of short-ter memory depending on what type of information is stored. It can be visual, spatial, verbal or auditory.[5]

4 Attention

There are several ways to characterize the attention depending on the branch of study. Philosopher William James describes attention as the process of taking possession of the mind, in clear and vivid form, of one out of what may seem several simultaneously possible objects or trains of thought. It implies withdrawal from some things in order to deal effectively with others. Zhu *et al.* defines attention as the cognitive process of obtaining and maintaining the alert state, orienting to sensory events, and regulating the conflicts os thoughts and behavior.[25], [10]

On the other hand, attention can be described in physiological terms as the brains areas that influence the operation of other areas. In this case attention is normally divided into three specific areas, called attentional networks. This networks commonly designated as brain circuits relate to: executive control, spatial orienting and alertness. This neural-based systems include the suprachiasmatic nucleus - circadian rhythm, the hypothalamo-pituitary-adrenal axis, and limbic system. Also, alertness may be modulated by metabolic systems and substrates such as thyroid, glucose, oxygen and electrolytes. [19].[20],[14],[24]

The state of attention for every individual correlates with vigilance, which refers to the ability to sustain attention and respond appropriately to demands and changes in the environment. Many studies have been made in this field regarding the identification of personality and ability traits that may relate to performance efficiency in vigilance tasks.[23]

5 Sleep, Attention and Short-Term Memory Correlation

Sleep deprivation can significantly impair sustained attention and STM capabilities. Excessive sleepiness and decreased mental performance tend to diminish the ability to retain information and awareness of our surroundings.[13]

EEG and Functional Magnetic Resonance Imaging (fMRI) analysis during performance tasks, both for attention and STM tasks, in subjects under sleep deprivation have shown a decrease in neuron firing and cortex

[1]The formation of long-term memories requires new gene expression[4]

activation.[13][20]

This conclusion indicates a strong relation between sleep and these cognitive functions, where sleep disorders can substantially diminish human cognitive capabilities, hence, being very important to treat patients under such conditions.[13][2]

6 Assessment Tools

In order to correctly describe sleep patterns for further diagnosis of sleep disorders, physicians and psychologists need assessment tools capable of providing accurate and relevant information about sleep routines and associated disturbances. Several objective and subjective methods exist for laboratory, hospital and home environments.[22]

The assessment tools used in the prototype described in this work are:

Sleep Diaries A sleep diary is, commonly, a paper questionnaire with the objective of recording the patients sleep habits, latencies, nighttime awakenings and behavioral data. To facilitate the diagnosis the patients must complete the diary on a daily basis, for at least 8 days, providing information such as *time went to bed, time to fall asleep, wake up time, number of awakenings, number of naps, length of naps, etc.*.[18]

Psychomotor Vigilance Task (PVT) The objective of this task is to measure the sustained attention of the subject by calculating their reaction time to a visual stimulus. PVT is a very reliable performance task, although, the duration of the task (5-10 minutes) may not be practical in several situations.

N-back Task The n-back task is used to measure working memory levels.[12] The concept of the n-back task is quite simple. A series of stimulus appear in order, and the user must always give an answer according to the previous ones.

Visual Scales Visual scales are a very useful way to measure sleepiness and sleep related mental states (like drowsiness). Several scales, for different purposes have been made throughout the years. Most scales are based on a self-reported subjective assessment, which can lead to errors, nevertheless, this process has shown to be very precise, providing useful information for the assessment of sleep.[11]

7 System Architecture and Outputs

7.1 Diary

The main feature in the ePP is the electronic sleep diary. The standard sleep diary from U.S. National Library of Medicine was used as base model.[18]

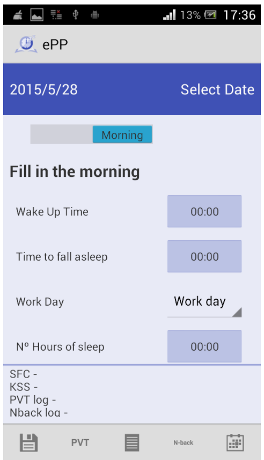


Figure 1: Screenshot of the Diary feature.

Figure 1 shows the screen for the electronic sleep diary.

The diary can be divided in two sections. the main area, where the actual diary is located and the action bar, which can appear split in top and bottom, as seen in Figure 1, or only on top, depending on the screen size.

The main area is where the information to be filled is placed. this info is divided in *Evening* and *Morning* info, according to the time of the day the user should fill it. To navigate into the specific part of the day the user wants, a switch button on the top of the screen must be selected accordingly.

The lower part of the diary is a log containing all the data for the visual scales, PVT and N-back tasks, thus, providing all the information for that specific date. This way the user can check its performance levels and analyze their routine.

When the user opens this feature it will be displayed the diary for the current day. To improve User Experience (UX), it is possible to navigate throughout the different days. Swiping left or right allows the user to go back one day or advance one, respectively. There is also the possibility of specifying the date by pressing the *Select Date* button.

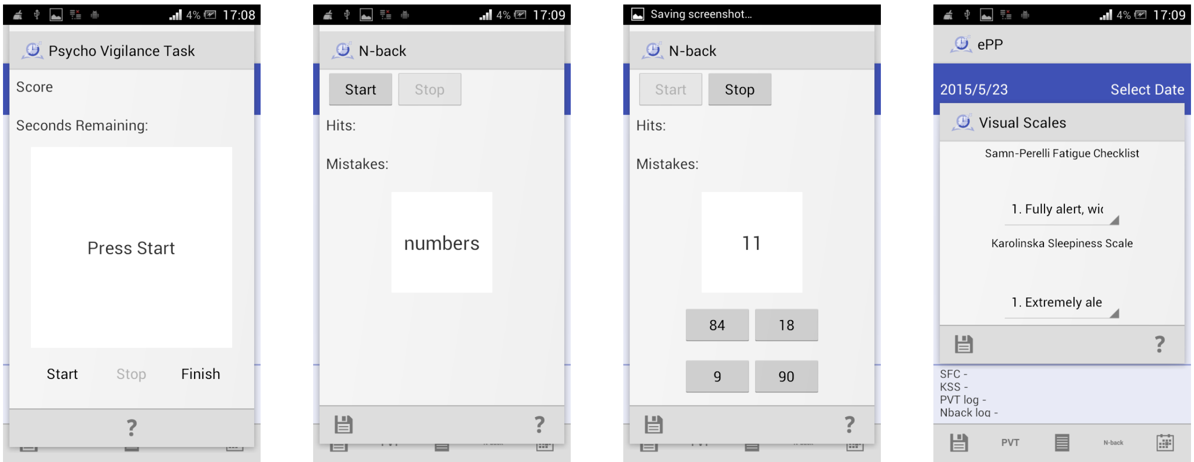
The second section, the action bar, is composed by the following buttons:

1. *Save* - Save the inserted data into the database[2] 2. *PVT* - Access the PVT feature. 3. *N-back* - Access the N-back feature. 4. *Visual Scales* - Access the Visual Scales feature. 5. *Go to present day* - Automatically go to the present day diary without the need to swipe multiple times neither insert it in *Select Date*. 6. *Export* - Export the database for further analysis . 7. *Help* - Alert dialog with help about the diary.

The user has three different typer of inputs to provide in this feature. Number selection, in all the fields where times should be presented, text input, for *complaints* and *other*, where the user should provide any information he might find useful. and item selection, where a list of pre-determined options is presented.

[2]The user does not need to press this button to actually save the data. The application has all the necessary safeguards, so, in case the user forgets to save, the info is not lost.

7.2 PVT, N-back Task and Visual Scales



(a) PVT task feature. **(b)** N-back before start. **(c)** N-back after start. **(d)** Sleep Scales feature.

Figure 2: N-back and Visual Scales features

In the PVT feature, after the user presses *Start*, the countdown timer starts and the test begins. The duration for a full trial is 120 seconds. The application displays a message *get ready...* and as soon as the message *Touch Me* appears, it must, as quickly as possible, press the white square. The stimuli are generated with random delays so no habituation occurs. The system calculates the time between the message is displayed and the click on the square.

In the N-back screen, a white square, where the stimuli will be presented, and two buttons (start and stop) are visible. After pressing the start button, a number will appear in the white square for 1 second. After this, the number changes and four buttons with four different answers appear below the white square.

The user must select the correct answer corresponding to the previous number. After the selection, the number changes again as well as the four answers. The user must always select the correct answer corresponding to the previous number presented in the white square. The process repeats itself for 50 trials.

The application calculates the time the user takes to answer, the number of correct answers and the number of mistakes. The results are presented in the form of Adjusted Hit Rate (AHR).

An AHR = 0 represents a response level of 50%; all correct responses with no errors means an AHR = 1; all incorrect responses represents an AHR = -1

For this application two visual scales,SFC and KSS, were implemented in a dialog that prompts after the user presses the *Visual Scales* button in the diary feature. The user must choose the correct options from the lists according to his subjective evaluation of sleepiness and drowsiness, respectively.

7.3 Attention Monitor

This feature is an all new concept for, as it name suggests, monitoring attention, throughout long periods of time.

Starting from the PVT concept a new approach was designed. Just like the PVT, the system will measure the user sustained attention. The user will be presented with different stimuli over time, to which he should respond as quickly as possible. Three different stimuli and two ways of giving a response were implemented. The system is adaptive, working in closed chain.

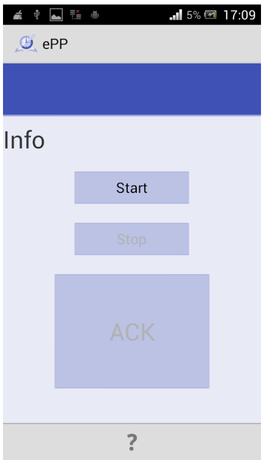


Figure 3: Screenshot of the Attention Monitor feature.

In Figure 3, its possible to observe the *Attention Monitor* feature of the application.

When the user presses start the application will search the device for the presence of three different hardware that will produce different stimuli. First the speaker for auditory stimuli, next the presence of a camera flash for visual stimuli, and finally, a vibrator for tactile stimuli.

After gathering the information about the available hardware for stimuli production, the system randomly chooses one of them, which will be used for the first five trials.

During these five trials the delay between stimuli and their intensity is constant.

After the first five trials the system calculates the mean response time of the user, and then, recalculates the values for the parameters of the next stimulus. From now on, all stimulus are produced randomly between the hardware options, with parameters according to the mean response time of the last five trials.

The user must give a signal of Acknowledge (ACK) to the system. It can be done either by pressing the ACK button on the screen or by pressing the button on the headset[3].

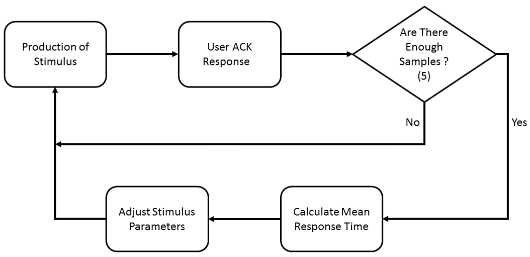


Figure 4: Flowchart for the closed chain feedback in the Attention Monitor feature.

If the user takes more than 30 seconds to give an ACK signal, the system activates an alarm.

[3]Currently the headset must be connected by the audio jack, as bluetooth headsets are not yet supported. Any common headset with a button to answer calls can be used.

The main objective of this system is to monitor attention during work-hours, e.g., monitor the attention of the driver in a bus trip, or monitor a pilots attention in a long-haul flight.

7.3.1 Graphics

The Graphics feature is only related to the Attention Monitor results. In this feature the user can select and view their performance results during a specific task. In the dropdown button on the top of the screen all the performed tasks identified with date and time are presented. After selection, the graphic corresponding to that task will appear. This graphical representation shows the reaction times (y-axis) over for the duration of the entire task (x-axis).The user can pan and zoom as intended. With this visual interaction the user can analyze their performance ratings and relate them with specific events during the task, for example, an increase in reaction times corresponding to the morning hours where the subject reported more sleepiness.

All the information gathered by the application can be exported to an .csv file for further analysis by a physician or psychologist.

8 Conclusion

The Electronic Psychological Profiler turned out to be a very versatile application in their midst, with several features that help the physician in the assessment of psychological disorders. It is a very easy to use and as an Android app can be used by a large portion of the population.

For future developments the most important aspect relies in the creation of a back-end solution that uses the capabilities of cloud storage. With such application the physician could monitor patients in real time, therefore being capable of adapting treatments and introducing new ones. A more visual appealing software for data analysis would be of highly importance, but with the ability to also use the big data capacities of spreadsheet calculations.

With the available mobile data plans, almost everyone is connected to the Internet, this way the use of cloud services would withdraw the need for patient concerns related to database exports and the need to send them for the physician for analysis.

Using the feedback from patients the User Interface (UI) can also be improved, finding better ways for the user to cycle between features inside the application. One possible way to overcome this issue may rely in using the fragments behavior in UI.[7] One possible disadvantage for this method may be in the fact that only newer devices support that feature, nevertheless, with the current growing rate of the smartphone market that may not be a problem.

Transition to other platforms should also be in the horizon, because this way, more people can be covered. The main Operating Systems (OS) to address are IOS and Windows Phone, as combined with Android, account for over 98% of the smartphone market.

In mobile application development, for the current OS, possibilities are endless and many additions to this platform can be made. From adding more performance tasks to inclusion of more sleep scales. Also, using the sensors embedded in the smartphone its possible to build actigraphs, oximeters and much more. Nowadays, several new technologies that can be paired with android devices are appearing in the market, such as Myo

Armband from Thalmic Labs Inc. These devices can help building extensive platforms for physiological and psychological assessment.

Another very important aspect for future work is the validation of the purposed Attention Monitor feature. Without relevant clinical findings that may correlate the veracity of the results, it wont be possible to spread the technology to other studies.

In conclusion, the Electronic Psychological Profiler, is a powerful application that integrates various systems that otherwise would be separated, requiring more concerns for the patient.

It wont be possible to overcome the knowledge acquired by a physician over years of practice, nevertheless, applications such as the ePP accelerate a process that must be as quickly as possible, for better and accurate disorder assessment.

References

[1] American Academy of Sleep Medicine. *The international classification of sleep disorders.* 2001.

[2] Clare Anderson and James a. Horne. Do we really want more sleep? A population-based study evaluating the strength of desire for more sleep. *Sleep Medicine*, 9(2):184–187, 2008.

[3] Clare Anderson, Charlotte R. Platten, and James a. Horne. Self-reported 'sleep deficit' is unrelated to daytime sleepiness. *Physiology and Behavior*, 96(4-5):513–517, 2009.

[4] Malka Cohen-Armon, Leonid Visochek, Ayelet Katzoff, David Levitan, Abraham J Susswein, Rodika Klein, Mireille Valbrun, and James H Schwartz. Long-term memory requires polyADP-ribosylation. *Science (New York, N.Y.)*, 304(5678):1820–1822, 2004.

[5] Nelson Cowan. What are the differences between long-term, short-term, and working memory? Nelson. *NIH Public Access*, 6123(07):323–338, 2009.

[6] Karl H. Pribram George A. Miller, Eugene Galanter. *Plans and the Structure of Behavior.* Holt, Rinehart and Winston, Inc, 1960.

[7] Google. Android Developer, 2014.

[8] Cameron D. Harris. Neurophysiology of sleep and wakefulness. (JANUARY 2006), 2015.

[9] By Max Hirshkowitz. Polysomnography - Understanding this technology past might guide future developments. (october):26–28, 2014.

[10] W. James. *The Principles of Psychology.* New York, 1890.

[11] Murray W Johns. *What is Excessive Daytime Sleepiness ?* 2009.

[12] Lisa Lejbak, Margaret Crossley, and Mirna Vrbancic. A male advantage for spatial and object but not verbal working memory using the n-back task. *Brain and Cognition*, 76(1):191–196, 2011.

[13] Julian Lim, Jiat Chow Tan, Sarayu Parimal, David F. Dinges, and Michael W L Chee. Sleep deprivation impairs object-selective attention: A view from the ventral visual cortex. *PLoS ONE*, 5(2), 2010.

[14] Gerald Matthews and Moshe Zeidner. Individual differences in attentional networks: Trait and state correlates of the ANT. *Personality and Individual Differences*, 53(5):574–579, October 2012.

[15] Robert Y. Moore. Suprachiasmatic nucleus in sleep-wake regulation. *Sleep Medicine*, 8(SUPPL. 3):27–33, 2007.

[16] M. Y. Münch, S. W. Cain, and J. F. Duffy. Biological rhythms workshop IC: Sleep and rhythms. *Cold Spring Harbor Symposia on Quantitative Biology*, 72:35–46, 2007.

[17] M. Tsodyks O. Barak. Working models of working memory. *Current Opinion in Neurobiology*, (25):20–24, 2014.

[18] National Library of Medicine. Printable sleep diary, 2014.

[19] B S Oken, M C Salinsky, and S M Elsas. Vigilance, alertness, or sustained attention: physiological basis and measurement. *Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology*, 117(9):1885–901, September 2006.

[20] Michael I Posner, Brad E Sheese, Yalçin Odludas, and YiYuan Tang. Analyzing and shaping human attentional networks. *Neural networks : the official journal of the International Neural Network Society*, 19(9):1422–9, November 2006.

[21] Patricia a Reuter-Lorenz and C C Sylvester. The Cognitive Neuroscience of Working Memory and Aging. First(8):186–219, 2005.

[22] Annette Richardson, Wendy Crow, Elaine Coghill, and Christopher Turnock. A comparison of sleep assessment tools by nurses and patients in critical care. *Journal of Clinical Nursing*, 16(9):1660–1668, 2007.

[23] Tyler H. Shaw, Gerald Matthews, Joel S. Warm, Victor S. Finomore, Leanne Silverman, and Paul T. Costa. Individual differences in vigilance: Personality, ability and states of stress. *Journal of Research in Personality*, 44(3):297–308, June 2010.

[24] Noam Weinbach and Avishai Henik. Phasic alertness can modulate executive control by enhancing global processing of visual stimuli. *Cognition*, 121(3):454–8, December 2011.

[25] Bi Zhu, Chuansheng Chen, Robert K Moyzis, Qi Dong, Chunhui Chen, Qinghua He, Jin Li, Jun Li, Xuemei Lei, and Chongde Lin. The DOPA decarboxylase (DDC) gene is associated with alerting attention. *Progress in neuro-psychopharmacology and biological psychiatry*, 43:140–5, June 2013.

[26] Ioná Zalcman Zimberg, Ana Dâmaso, Mariana Del Re, Aline Millani Carneiro, Helton de Sá Souza, Fábio Santos de Lira, Sergio Tufik, and Marco Túlio De Mello. Short sleep duration and obesity: Mechanisms and future perspectives. *Cell Biochemistry and Function*, 30(6):524–529, 2012.